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PORTABLE LIFE SUPPORT EQUIPMENT FOR APOLLO APPLICATIONS MISSIONS

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

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By J. Travis Brown

INTRODUCTION

The first four Apollo Applications Program (AAP) missions will involve several payloads docked together in a cluster configuration. Missions 1 and 2 (mission A) cluster configuration will consist of a Saturn IVB (S-IVB) spent stage, which will be converted into an orbital workshop, an airlock module (AM), a multiple docking adapter (MDA), and an Apollo command/service module (CSM). Following the 28-day mission A, mission B (56 days) will be flown. This mission will consist of the mission A cluster, with a revisiting command/service module, plus a lunar module/Apollo telescope mount (LM/ATM), figures 1 and 2. The extravehicular activity (EVA) and intravehicular activity (IVA) life support requirements for both of these missions are analyzed in this report. Portable life support system concepts are investigated, and the equipment requirements that best support these missions are established.

MODES OF OPERATION

The modes of operation that require portable life support equipment are as follows:

Extravehicular activity: Operations carried out by a suited crewman at ambient pressures below 3.0 psia.

Intravehicular activity: Operations carried out by a suited crewman in an environment of 3.0 psia or greater with the suit pressurized to 3.9 psi above ambient pressure.

Suit vented: Operations carried out by a suited crewman in a pressure environment of 3.0 psia or greater with the suit pressure equal to local ambient.

NOTE: The above definitions are for purposes of this document only.

EVALUATION GROUND RULES

The following basic ground rules were used in choosing the portable life support equipment to best support the AAP missions 1 to 4.

Priority factors for rating of different systems:

1. Probability of accomplishing all tasks

2. Cost

3. Spacecraft modifications

4. Total weight

The system shall have minimum volume, high reliability, and uncomplicated checkout.

CONSTRAINTS

The following technical constraints were adhered to in the study effort:

1. Two men EVA simultaneously, one man IVA

2. EVA excursions will be a nominal 3 hours

3. Prebreathing time — 45 minutes

4. No low-pressure umbilical connections or disconnections in a vacuum as an operational mode

5. Provide hardline communications and biomedical data (excluding lunar portable life support system)

6. The EVA life support system shall provide for the following emergencies with allowable degradation as shown:

   a. Loss of primary cooling mode

      (1) 30 minutes

      (2) 300 Btu maximum body heat storage

      (3) 2000 Btu/hr metabolic rate

b. Loss of primary ventilation mode

(1) 30 minutes

(2) 15 mm Hg maximum PCO_2

c. Loss of primary oxygen supply

(1) 30 minutes

(2) Audible and visible warnings if emergency O_2 is automatically actuated

d. Fail open of any ventilation loop relief valve

(1) 30 minutes

(2) Suit pressure maintained

(3) Relief valve override or sufficient makeup O_2

RECENT GUIDELINE CHANGES

Early AAP EVA/IVA equipment studies were based on then-current guidelines. Mission and spacecraft ground rules have since changed, and the following is a list of the more important changes since the early AAP studies:

1. EVA equipment volume is more critical, from both the stowage standpoint and the crewman mobility standpoint.

2. Previous studies assumed that the AM water system was serviced at launch. Present guidelines indicate that the crewmen must charge the water system.

3. Previous studies assumed that the command module (CM) crewman would remove the CM probe and drogue on mission B. Present plans are for the two lunar module (LM) crewmen to transfer through the MDA and remove the CM probe and drogue.

4. Simplicity of EVA equipment checkout, service, and deservice is considered to be more critical.

5. "Order of preference" of comparison factors has changed, such that cost is of higher preference than weight.

6. Missions are better defined than for early AAP studies.

7. Many spacecraft/equipment interface problems have been identified.

8. Oxygen supply system changed from an AM gas system to a CSM cryogenic system with 20-lb/hr flow capability.

9. Contingency EVA transfer from LM to CM possible with O_2 bail-out type system. This was previously considered unacceptable.

10. Total EVA and IVA hours changed on both missions A and B.

SYSTEMS CONSIDERED

Among the many portable life support system combinations considered, the following were chosen as candidates for the final trade-off. Each is capable of supporting AAP missions 1 to 4 requirements.

1. Pressure control unit (PCU)
    a. Emergency oxygen pack (EOP) — 15 minutes
    b. Supplementary emergency oxygen supply (SEOS) — 30 minutes
2. Lunar portable life support system (PLSS)
3. Modified portable life support system (O_2, electrical umbilical)
4. Portable environmental control system (PECS)
5. New system (O_2, electrical umbilical)
6. New system (O_2, electrical, H_2O umbilical)
7. Suit ventilation unit (SVU)
8. Other equipment
    a. Visor-type helmet
    b. Demand mask for prebreathing
    c. Mask for IVA (continuous purge)
    d. Umbilicals

Pressure Control Unit

The PCU is chest-mounted, as shown in figure 3, with oxygen supplied from an umbilical and from the emergency oxygen pack (EOP). Two quick disconnects provide the capability of transferring from the umbilical to another oxygen source, such as the supplementary emergency oxygen system (SEOS). As shown in figure 4, oxygen is supplied to the medium pressure loop, where it is metered to the suit by the oxygen selector valve. A higher than normal flow setting of the valve will be provided for backup gas cooling of the crewman. Oxygen flows out of the suit to the PCU suit relief valve, which serves as a suit vent and as a suit pressure control. A demand regulator senses downstream suit pressure and automatically supplies an additional O_2 flow if suit pressure drops below 3.3 psi. The EOP automatically provides oxygen in the event of an umbilical failure. The EOP supplies oxygen (15 minutes) until the EVA crewman can transfer to the SEOS, which he manually connects to the PCU for an additional 30 minutes of oxygen. The prime cooling mode associated with the PCU is achieved by the use of cooling water circulated from the spacecraft heat rejection system to the liquid-cooled garment via umbilical.

Lunar Portable Life Support System

The lunar PLSS, shown schematically in figure 5 contains closed-loop oxygen ventilation, a cooling-water circulation loop, a sublimator heat rejection source, a primary oxygen supply, a battery power supply, and a space suit communications system. There is no umbilical associated with employment of this system. The ventilation loop provides CO_2 removal, humidity control, and O_2 makeup from the primary oxygen supply. The cooling-water circulation loop provides heat transport from the liquid-cooling garment to the sublimator, which rejects heat by sublimation of stored water to a vacuum environment. The space suit communications system provides the following: two-way voice communications between crewman inside the spacecraft and the EVA crewmen; processing of physiological, environmental, and expendable status outputs for telemetry transmission to the spacecraft; and generating signals for audible alarm of environmental conditions.

Modified PLSS (Electrical and O_2 Umbilical)

The battery and primary O_2 bottle are used as backups, with electrical/communications and oxygen being supplied through an umbilical for normal operation. Figure 6 is a schematic illustration of the modified PLSS and shows how the umbilical/PLSS interface is configured. In the event the umbilical or spacecraft O_2 supply is lost, the emergency O_2 supply automatically actuates due to the O_2 regulator configuration; at this time, visible and audible warnings will be triggered. An O_2 valve allows a high O_2 flow to bypass the 3.9 psi regulator, thus providing a means of backup cooling from the umbilical supply. The higher flow rate vents at the suit relief valve, which is an added component to the PLSS. This unit can be used with or without an umbilical, but without an umbilical, it will not have backup electrical/ communications.

Portable Environmental Control System

Figure 7 schematically illustrates the PECS, which contains closed-loop oxygen ventilation, a cooling-water circulation loop, an evaporator heat rejection source, an oxygen supply, a battery, and a liquid-to-liquid heat exchanger. The system expendables are sized, such that EVA may be performed with or without an umbilical, and IVA can be accomplished by utilization of an umbilical which contains circulating cooling water. When operating on an O_2, electrical umbilical, the evaporator serves as the prime heat rejection source with umbilical high flow gas as a backup. If an O_2, electrical, water umbilical is utilized, the PECS liquid-to-liquid heat exchanger serves as the prime cooling mode, with the evaporator utilized as a backup. Electrical power and communications may be provided by an umbilical; or electrical power can be obtained from the PECS battery, and a transceiver unit can be installed for biomedical/communication.

New System (O_2, Electrical Umbilical)

Figure 8 is a schematic of the new system, which is designed specifically for AAP missions 1 to 4 requirements. The system contains closed-loop oxygen ventilation, a cooling-water circulation loop, an evaporator heat rejection source, an emergency O_2 supply, an emergency power supply, and an evaporative water reservoir. The system is dependent upon an umbilical for primary oxygen supply, for high-flow oxygen backup cooling, for electrical power, and for biomedical/communications. The evaporator is the prime mode of cooling, while both the battery and oxygen bottle serve as backups. This system has self-contained capability for emergency cases where umbilical independence is necessary, but in this event, would be time-limited (i.e., the O_2 and battery sized for 30 minutes).

New System (O_2, Electrical, H_2O Umbilical)

This new system, figure 9, is also designed specifically for AAP missions 1 to 4 requirements. This system is similar to the new system explained in the previous paragraph, except that it employs a liquid-to-liquid heat exchanger for water umbilical use. The evaporator serves as a backup, but unlike the PECS, the evaporator water supply, oxygen supply, and battery are sized for a 30-minute emergency situation. The system can be used for IVA with a water umbilical and has self-contained capability for EVA, but only for the 30-minute emergency time.

Suit Ventilation Unit

The SVU, which is for IVA and suit-vent modes only, is a simplified PCU. It feeds umbilical-supplied oxygen to the suit at several different flow rates, as determined by the O_2 valve setting. Also, it serves as a suit relief valve, back-pressurizing the suit to 3.9 psia; and, it provides a means to vent a deflated suit while in a pressurized cabin. The unit is used primarily in a pressurized cabin, but also serves as an emergency pressurization device in case cabin pressure is lost. The SVU will employ an aneroid-backup to all modes of operation, such that during an exposure to vacuum conditions, the suit will be maintained at 3.9 psi above ambient and vented when the O_2 valve is actuated. Crewman cooling is accomplished by the use of spacecraft cooling water, which is circulated from the spacecraft heat rejection system to the liquid-cooled garment via an umbilical.

Other Equipment

A visor-type helmet is advantageous for IVA and suit vent modes of operation, since it allows breathing of the conditioned cabin atmosphere with an open visor and yet maintains the helmet in a donned position ready for pressurization of the suit. The visor-type helmet would save oxygen and tankage weights, since O_2 would not be flowing unless required (i.e., can breathe the cabin atmosphere); whereas, if a bubble-type helmet is used, O_2 vent flow is continually required.

The PLSS has no means of prebreathing and the PCU and SVU require high flow rates. A demand-type mask is therefore recommended for prebreathing requirements of the AAP missions.

A low-profile O_2 mask is desirable for O_2 conservation during IVA when an open-loop O_2 system is being employed. Even if an EVA system is chosen that is capable of also supporting IVA, a chest-mounted open-loop system will be used for the maneuvering-unit experiment.

Two basic types of umbilicals were considered: one containing O_2 and electrical supplies; the other furnishing cooling-water supply and return (from the spacecraft ECS) in addition to O_2 and electrical.

MISSION ANALYSIS

Missions 1, 2, and 3, 4 were analyzed with respect to portable life support equipment and associated hardware requirements. This investigation included spacecraft requirements, crewman tasks, and portable life support equipment combinations capable of supporting these requirements. Each set of equipment that was considered in the final trade-off is capable of satisfying present AAP requirements for missions 1 to 4. The following requirements were found to be desirable (or in some cases mandatory), no matter which set of EVA/IVA life support equipment is chosen.

Missions 1 and 2

For normal docking of the CSM to the AM and initial MDA entry by the crew, the MDA and AM will be pressurized. The suited crewmen will then enter the pressurized MDA with either O_2 vent flow to the suit or with a visor-type helmet donned. It is concluded that a visor helmet should be utilized, due to the oxygen savings benefit (i.e., use open visor with no O_2 flow to suit unless needed). It is also desirable to have a water-cooling system in the CM to support water umbilicals for the following reasons:

For the contingency EVA (i.e., MDA does not pressurize), the crewmen must have a water-cooling umbilical for performing EVA with a PCU-type system. If a system is used that employs evaporative cooling, a water umbilical is needed for crewman cooling during system checkout while in a pressurized cabin.

For normal operation, the crewmen must enter the MDA and the AM and charge the AM ECS water. Water cooling must be provided through an umbilical for this operation.

Missions 3 and 4

The visor helmet is also advantageous for missions 3 and 4. A water-cooling system to support a water umbilical is required in the LM for the following reasons:

For normal operation, the two LM crewmen must remove the LM probe and drogue, transfer through a pressurized MDA to the CM, and remove the CM probe and drogue. They must also charge the AM ECS water system. Metabolic heat rejection must be accomplished by water umbilicals during these operations.

In the event EVA must be accomplished from the LM, for either the ATM contingency mission or for the cluster mission when the MDA does not pressurize, water cooling via an umbilical is required for the PCU system or during EVA equipment checkout if an evaporative cooling-type system is employed.

SYSTEM ADVANTAGES AND DISADVANTAGES

All of the EVA systems chosen as candidates for the trade-off are capable of meeting the AAP missions 1 to 4 requirements, but each has definite advantages and disadvantages. Each candidate EVA system is listed with its relative advantages and disadvantages.

Pressure Control Unit

Advantages:

1. Small volume

2. No recharge requirements

3. Minimum checkout requirements

4. EVA and IVA umbilicals same

5. No time-dependent PCU expendables, except emergency

Disadvantages:

1. Would have to use bailout bottle concept for contingency transfer from LM to CM

2. Requires large O_2 bottle for backup O_2 supply

3. Not self-contained (i.e., insufficient emergency O_2 for gas cooling)

4. Continuous high O_2 flow requirement

5. Present AM heat rejection system inadequate to provide water temperatures and heat removal capability

6. Requires two extra umbilicals in structural transition section (STS) in case AM fails to pressurize and crewman has to transfer from one umbilical to another in going from the AM to the MDA.

Lunar PLSS

Advantages:

1. Qualified, available, and will have EVA usage

2. Self-contained

Disadvantages:

1. Large volume (i.e., has been demonstrated that it is difficult to maneuver in truss area)

2. Less backup cooling and O_2 capability than other systems (OPS used for backup cooling)

3. Complex recharge requirements. The water recharge concept depends on gravity for "full-tank" assurance

4. Complex deservice requirements (e.g., LM condensate dump system is gravity-dependent, which requires a LM modification for contingency mission EVA capability)

5. No cooling capability in pressurized cabin

6. No provision for hardline communications or bioinstrumentation

Umbilical PLSS (O_2, Electrical Umbilical)

Advantages:

1. Adequate backup modes

2. No O_2 recharge or battery replacement requirements

3. No OPS required

Disadvantages:

1. Large volume (has been demonstrated that it is difficult to maneuver in truss area)

2. No cooling capability in pressurized cabin

3. Complex recharge requirements (water recharge concepts depend on gravity for "full-tank" assurance)

4. Complex deservice requirements (e.g., LM condensate dump system is gravity-dependent, which requires a LM modification for contingency mission EVA capability)

5. Oversized backup expendables for missions A and B

PECS (4 Hours Capability With or Without Umbilical)

Advantages:

1. Good backup modes

2. Minimum recharge

3. Cooling capability in pressurized cabin

4. Smaller than PLSS

5. Only system with 4-hour capability with or without an umbilical

6. Not as stringent on AM heat rejection system design as other H_2O umbilicals (i.e., has water boiler topoff capability or capability of using O_2, electrical umbilical with water boiler as prime heat rejection)

Disadvantages:

1. Oversized backup expendables for missions A and B

2. More new development involved than PLSS

3. Larger than PCU

New System (Electrical, O_2 Umbilical)

Advantages:

1. Good backup mode designs

2. Optimum sized backup expendables

3. Minimum size for closed-loop portable system

4. Smaller than PLSS and PECS

5. AM heat rejection system design not impacted as with H_2O umbilical systems

6. Very little service and deservice required

7. Self-contained capability (for 30-minute period)

Disadvantages:

1. More new development involved than PLSS

2. Cannot be used for a great length of time as a self-contained system

3. No cooling capability in pressurized cabin

4. Larger than PCU

New System (Electrical, O_2, H_2O Umbilical)

Advantages:

1. Good backup mode designs

2. Optimum sized backup expendables

3. Minimum size for closed-loop portable system

4. Smaller than PLSS and PECS

5. Minimum service and deservice required

6. Provides cooling capability in pressurized cabin

7. Self-contained capability (for 30-minute period)

Disadvantages:

1. More new development involved than PLSS

2. Cannot be used for a great length of time as a self-contained system

3. Present AM heat rejection system inadequate to supply the heat removal and water temperatures required

4. Larger than PCU

WEIGHT TRADE-OFF

A detailed weight trade-off was performed, which took into account spacecraft system weights, life support equipment weights, and expendables (including tankage). The guidelines are presented herein, and tables I and II show weight breakdowns for missions 1, 2, and 3, 4, respectively. Table III is a weight summary of the detailed weight charts.

Guidelines

Mission man-hours.-

	Mission A	Mission B
EVA	20	36
IVA	34	6
Prebreathing	4.5	9
Post-EVA	1.0	2.0

General.-

1. Suit purge O_2 for pre- and post-EVA:

Mission A — 9.9 pounds

Mission B — 19.8 pounds

Purge-times vary, depending on the flow capabilities of each system, but the total O_2 purged through the suit is the same.

2. Assumed that any open-loop system used for IVA will utilize a mask with an O_2 flow rate of 6.0 lb/hr

3. Prebreathing system — demand mask system, at 1.0 lb/hr per man

4. Prebreathing time — 45 minutes

5. CSM O_2 and cryogenic tankage penalty = (O_2 required) × (1.5)

6. CSM power penalty (including reactant tankage) for PCU EVA (i.e., requires 1500-watt heaters) = 1.85 lb/hr EVA

7. LM water umbilical support system

Fixed weight = 62 pounds

H_2O tankage = 5.5 pounds per 40 pounds H_2O

Water = 0.8 lb/hr EVA or IVA

8. AM water umbilical systems — 80 pounds (100 pounds for EVA H_2O umbilical systems)

9. Suit ventilation unit — 6 pounds

Pressure control unit.-

1. PCU	12 pounds
2. EOP (charged)	6 pounds
3. SEOS (charged)	32 pounds
4. Oxygen (EVA)	7.9 lb/hr
5. Oxygen (IVA with mask)	6.0 lb/hr

Lunar portable life support system.-

1. Charged PLSS	82 pounds
2. Charges OPS	38 pounds
3. PLSS control box	4.43 pounds

4.	LiOH recharge	6.03 pounds
5.	Battery	5.18 pounds
6.	Sublimator water	2.63 lb/hr EVA
7.	Oxygen	0.4 lb/hr

Portable environmental control system.-

1.	Charged PECS	96 pounds
2.	LiOH recharge	3.5 pounds
3.	Oxygen	0.4 lb/hr

New system (O_2, electrical umbilical).-

1.	System weight (charged)	65 pounds
2.	LiOH recharge	3.5 pounds
3.	Evaporative water	2.4 lb/hr EVA
4.	Oxygen	0.4 lb/hr

New system (O_2, electrical, H_2O umbilical).-

1.	System weight	65 pounds
2.	LiOH recharge	3.5 pounds
3.	Oxygen	0.4 lb/hr

Umbilicals.-

1. 60-foot O_2, electrical, H_2O umbilical — 40 pounds

2. 60-foot O_2, electrical umbilical — 20 pounds

COST ANALYSIS

The cost analysis includes the design, development, and qualification of the EVA and IVA equipment required to support missions A and B crew training, manned altitude chamber runs, and spacecraft testing exercises. The costs do not include ground support equipment, field support, or modifications to the LM and CSM for water umbilical systems. Also, some of the support equipment, such as O_2 masks, helmets, and suits are not considered in the cost analysis. Table IV presents a relative cost comparison of all candidate systems. Actual dollar values are not presented in this report.

CONCLUSIONS

In considering each system with respect to the rating factors, it is found that no set of candidate equipment qualifies as optimum for all rating factors. Even though the factors have an order of preference, it is difficult to establish a relative base of comparison (e.g., is a 2-million-dollar savings worth a weight disadvantage of 200 pounds, 500 pounds, 1000 pounds, etc.?).

"Probability of accomplishing all tasks" is best supported by the PCU, due to its small volume and minimum checkout, service, and deservice requirements. It is pointed out, however, that this rating factor is considered only as related to operational requirements. When contingencies are taken into account, the PCU, in most cases, is the less desirable of all systems, due to its emergency backup limitations.

The PCU system is the optimum system from a cost standpoint, but it should be kept in mind that if AAP requirements of the future dictate a more elaborate life support system, then the total cost would be greater than if development of a more elaborate system is presently initiated.

All combinations of EVA/IVA equipment are similar with respect to "spacecraft system impact." The systems utilizing water umbilicals for EVA, however, are more stringent on the spacecraft heat rejection system. This is due to the 40° F water temperature that must be provided during high metabolic heat rates, and to the total heat rejection capability that must be available to assure that overheating of a crewman does not occur while performing EVA. Also, for the PCU system, a large oxygen quantity is required; but the O_2 flow rate capabilities are not any more stringent than the other systems, since most of the other systems use high flow O_2 as a backup cooling mode and/or use the SVU (open-loop O_2 flow) for IVA and suit vent modes.

The weight trade-off shows that the PCU system has the greatest total weight, and that the two systems, which have cooling capability in a pressurized cabin (thus saving oxygen required by an open-loop system), offer the lowest weight penalties. It is also concluded that the open-loop PCU system is more weight-time critical than the other systems considered (i.e., any increase in EVA or IVA total time will increase total weight more with the PCU than with other systems).

The most flexible system and the system with the most growth potential to assure future mission requirements is clearly the PECS. The inherent flexibility associated with the liquid-to-liquid heat exchanger (i.e., capability of operation with or without an umbilical and to provide cooling while in a pressurized cabin), the metabolic rate level design, and the redundant and backup provisions have all evolved from findings of past portable life support equipment programs. The PECS thus offers the most elaborate and unique state-of-the-art life support system.

In summary, based on the guidelines of this study, and assuming that EVA/IVA requirements (total time, operational modes, or contingency modes) for AAP will not change, the PCU system is the more desirable of the systems considered. This conclusion, however, is dependent on one rationalization — that the cost advantage as shown in table IV is more desirable than the weight penalty as presented in table III. It should also be kept in mind that if mission requirements (operational or contingency) or total EVA or IVA times increase significantly, the PCU will more than likely fall into a less desirable category.

TABLE I.- MISSIONS 1 AND 2 WEIGHTS

EVA Life support system	PCU	Lunar PLSS	Umbilical (electrical, O_2) PLSS	PCU and lunar PLSS	PECS	New system: Electrical, O_2, umbilical	New system: Electrical, O_2, H_2O umbilical
IVA Life support system	PCU	SVU	SVU	PCU	PECS and SVU	SVU	EVA system and SVU
Oxygen	384.3	226.8	226.8	307.4	42.0	226.8	42.0
LiOH		24.1	24.1	12.1	52.5	14.0	52.5
H_2O		52.7	52.7	26.3		48.0	
Batteries		20.4		10.2			
CSM power/weight penalty	37.0			18.5			
Expendable total	421.3	324.0	303.6	374.5	94.5	228.0	94.5
EVA life support system(s)	36.0	174.0	174.0	111.0	192.0	130.0	130.0
SVU's, 6 lb each		12.0	12.0		12.0	12.0	12.0
EOP's (charged), 6 lb each	18.0			12.0			
SEOS's (charged), 32 lb each	64.0			64.0			
OPS (charged), 38 lb each		76.0		38.0			
Electrical, O_2, H_2O umbilical, 40 lb each	160.0	80.0	80.0	80.0	80.0	80.0	80.0
Electrical, O_2 umbilical, 20 lb each			40.0			40.0	
CSM cryogenic O_2 tankage	192.0	113.4	113.4	153.7	21.0	113.4	21.0
AM ECS water umbilical system	100.0	80.0	80.0	80.0	100.0	80.0	100.0
Equipment total	570.0	535.4	499.4	538.7	405.0	455.4	343.0
Total	991.3	859.4	803.0	913.2	499.5	683.4	437.5

TABLE II.- MISSIONS 3 AND 4 WEIGHTS

EVA Life support system	PCU	Lunar PLSS	Umbilical (electrical, O_2) PLSS	PCU and lunar PLSS	PECS	New system: Electrical, O_2, umbilical	New system: Electrical, O_2, H_2O umbilical
IVA Life support system	PCU	SVU	SVU	PCU	PECS and SVU	SVU	EVA system and SVU
Oxygen	364.8	80.0	80.0	222.4	46.4	80.0	46.4
LiOH		60.3	60.3	30.2	42.0	35.0	42.0
H_2O (includes LM umbilical cooling)	19.2	99.5	99.5	59.4	19.2	91.2	19.2
Batteries		51.0		25.5			
CSM power/weight penalty	66.6			33.3			
Expendable total	450.6	290.8	239.8	370.8	107.6	206.2	107.6
EVA life support system(s)	36.0	174.0	174.0	111.0	192.0	130.0	130.0
SVU's, 6 lb each		12.0	12.0		12.0	12.0	12.0
EOP's (charged), 6 lb each	18.0			12.0			
SEOS's (charged), 32 lb each	64.0			64.0			
OPS (charged), 38 lb each		76.0		38.0			
Electrical, O_2, H_2O umbilical, 40 lb each	160.0	80.0	80.0	80.0	80.0	80.0	80.0
Electrical, O_2 umbilical, 20 lb each			40.0			40.0	
CSM cryogenic O_2 tankage	182.4	40.0	40.0	111.2	23.2	40.0	23.2
LM ECS water umbilical system	67.5	67.5	67.5	67.5	67.5	67.5	67.5
Equipment total	527.9	449.5	413.5	483.7	374.7	369.5	312.7
Total	978.5	740.3	653.3	854.5	482.3	575.7	420.3

TABLE III.- WEIGHT SUMMARY

EVA system	IVA system	Mission A				Mission B			
		Expendables	EVA/IVA equipment	Spacecraft equipment	Total	Expendables	EVA/IVA equipment	Spacecraft equipment	Total
PCU	PCU mask	421.3	278.0	292.0	991.3	450.6	278.0	249.9	978.5
Lunar PLSS	SVU mask	324.4	342.0	193.4	859.4	290.8	342.0	107.5	740.3
Umbilical (electrical, O_2) PLSS	SVU mask	303.6	306.0	193.4	803.0	239.8	306.0	107.5	653.3
PCU and lunar PLSS	PCU mask	374.5	305.0	233.7	913.2	370.8	305.0	178.7	854.5
PECS	PECS SVU mask	94.5	284.0	121.0	499.5	107.6	284.0	90.7	482.3
New system (electrical, O_2, umbilical)	SVU mask	228.0	262.0	193.4	683.4	206.2	262.0	107.5	575.7
New system (electrical, O_2, H_2O umbilical)	SVU, EVA system mask	94.5	222.0	121.0	437.5	107.6	222.0	90.7	420.3

TABLE IV.- COST COMPARISON

EVA system	IVA system	Cost comparison
PCU	PCU, mask	1.0
Lunar PLSS	SVU, mask	1.79
Umbilical (electrical, O_2) PLSS	SVU, mask	1.77
PCU and lunar PLSS	PCU, mask	2.02
PECS	PECS, SVU, mask	2.65
New system (electrical, O_2 umbilical)	SVU, mask	2.54
New system (electrical, O_2, H_2O umbilical)	SVU and EVA system	2.42

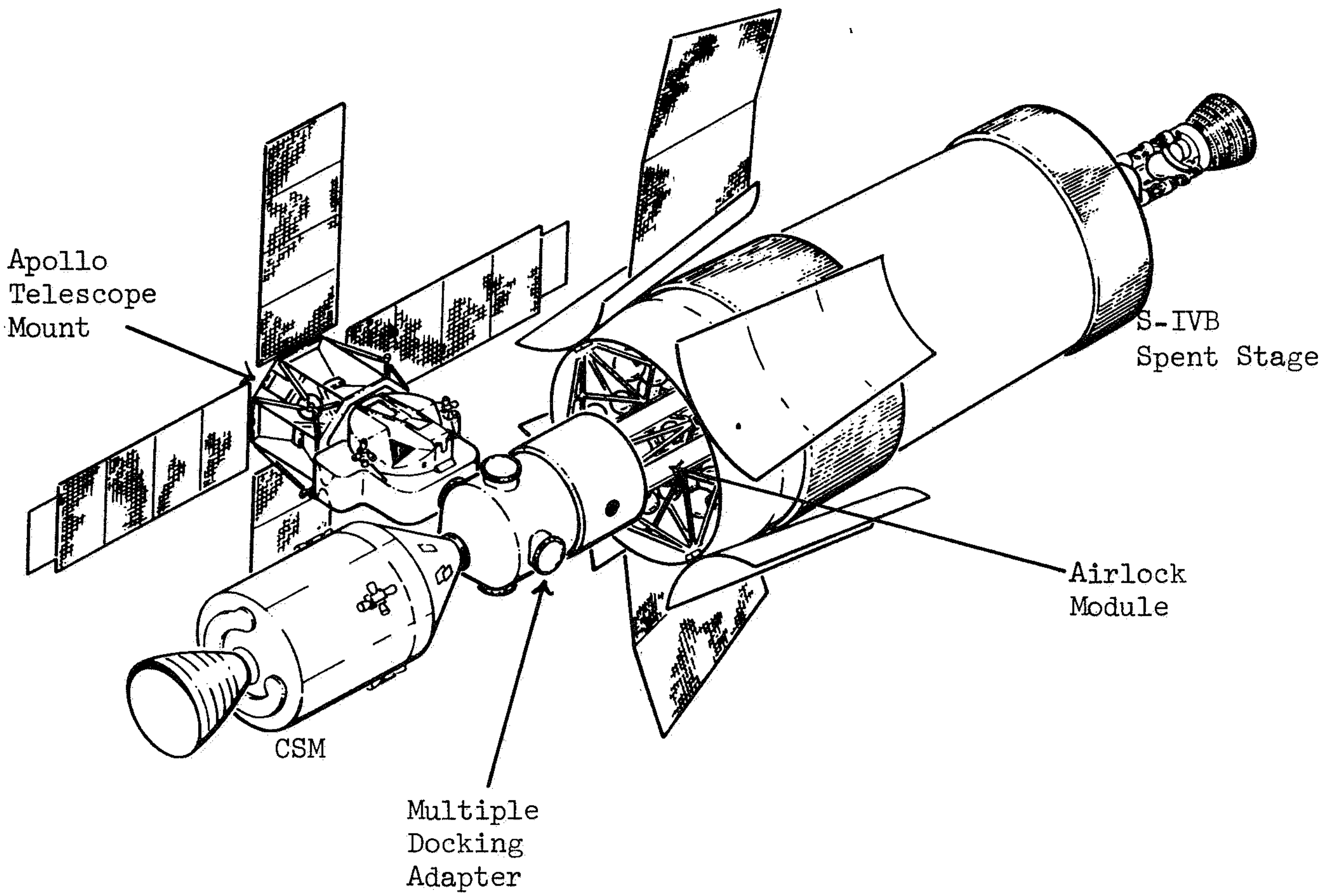

Figure 1.- The AAP missions 1 to 4 cluster configuration.

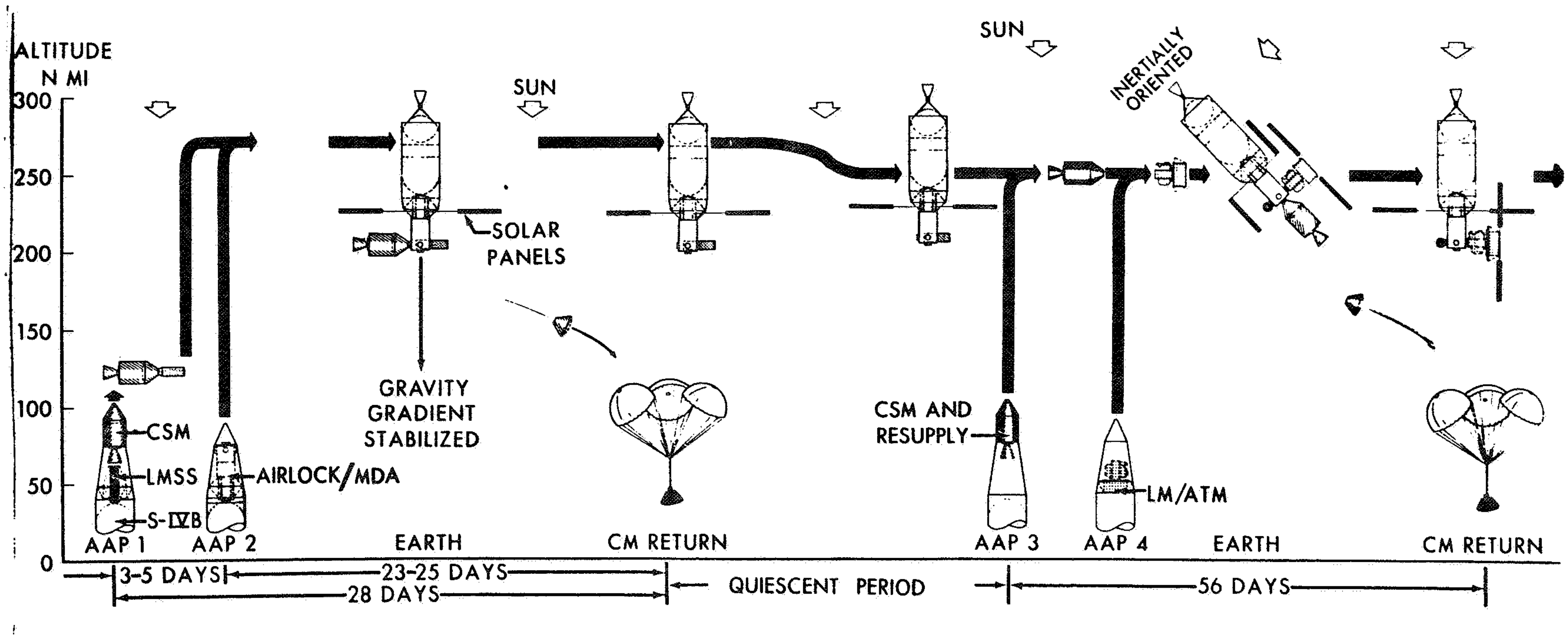

Figure 2.- The AAP missions 1 to 4 profile.

NASA-S-68-2824

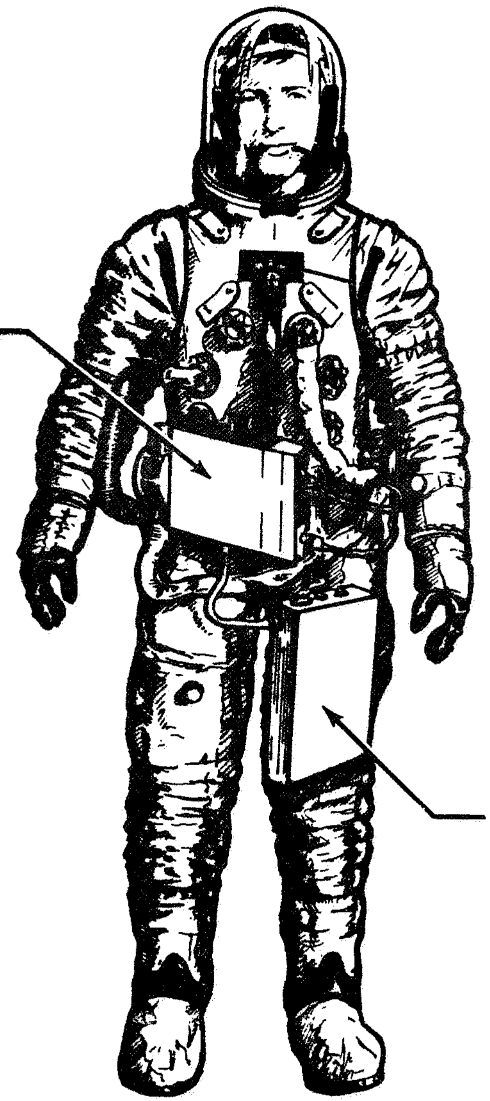

Figure 3.- Pressure control unit configuration.

NASA-S-68-2823

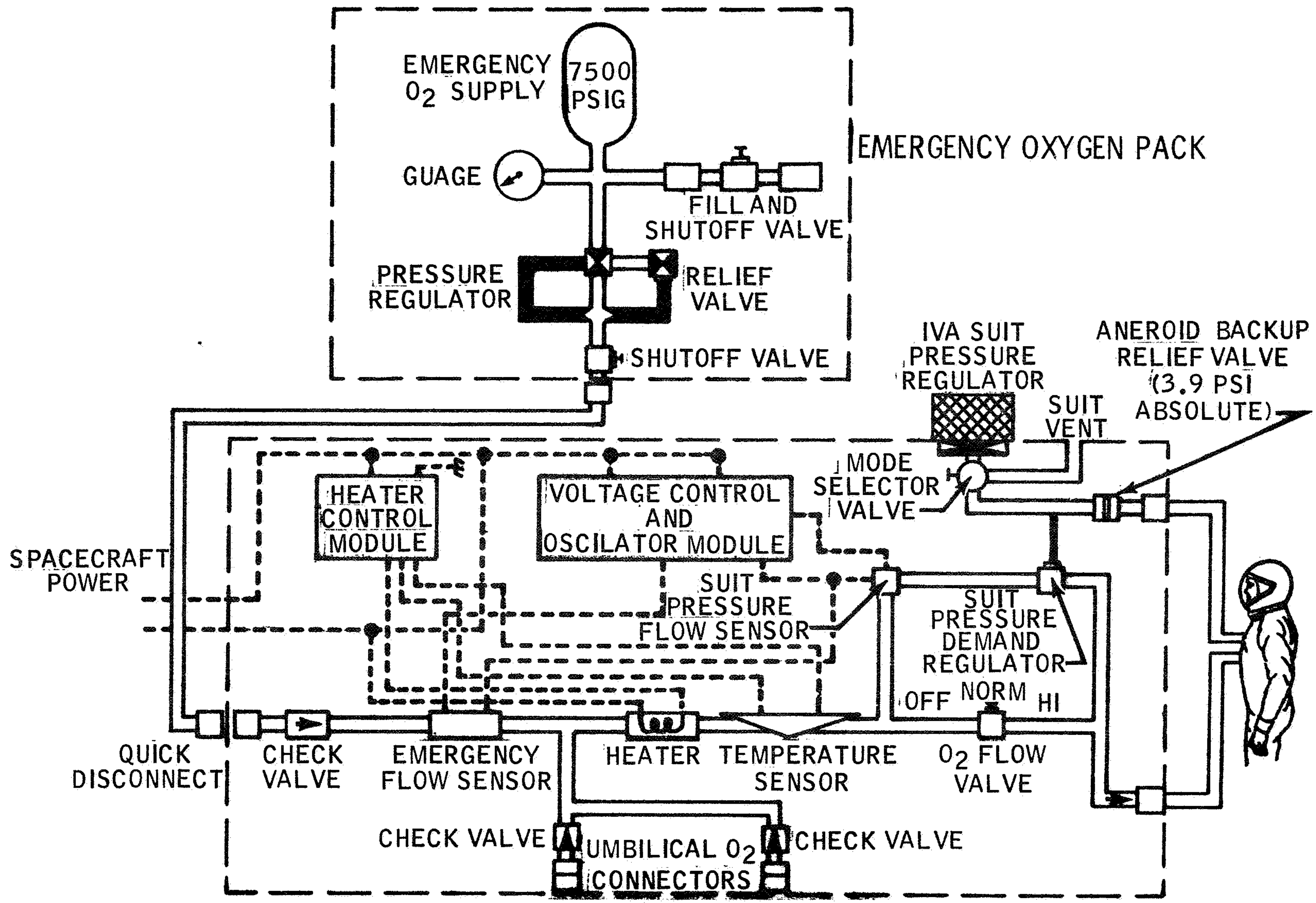

Figure 4.- Pressure control unit schematic.

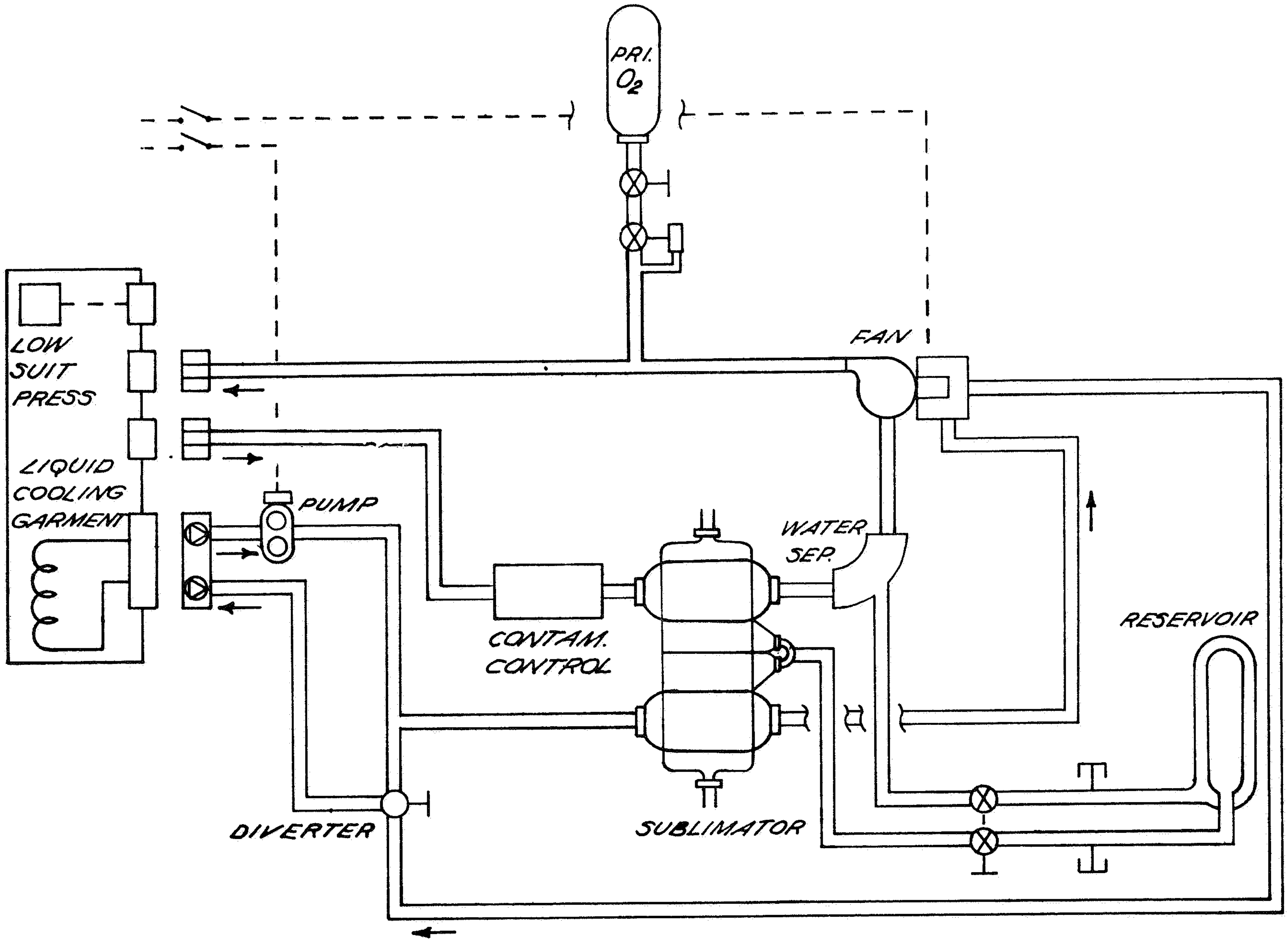

Figure 5.- Lunar portable life support system.

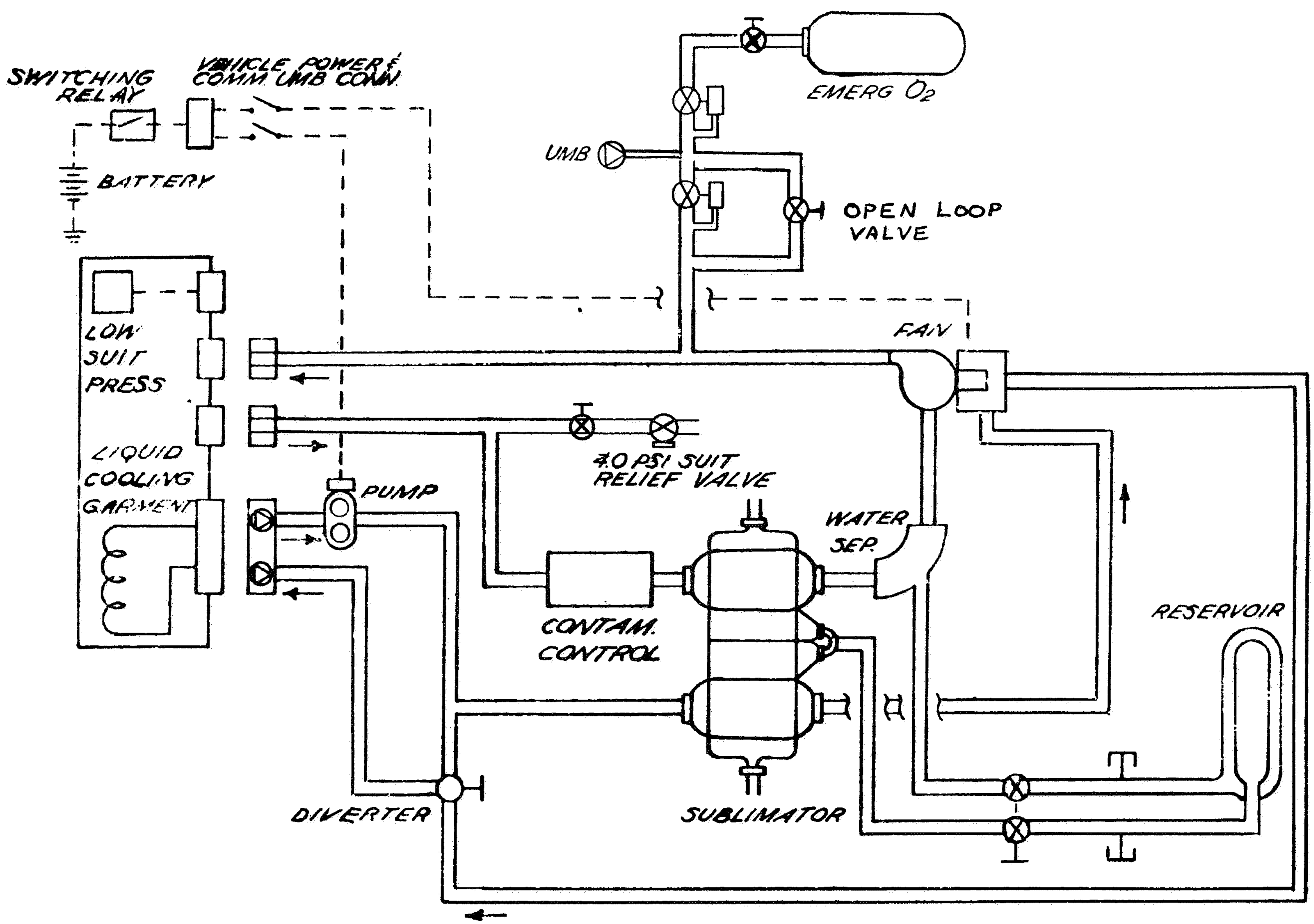

Figure 6.- Modified portable life support system.

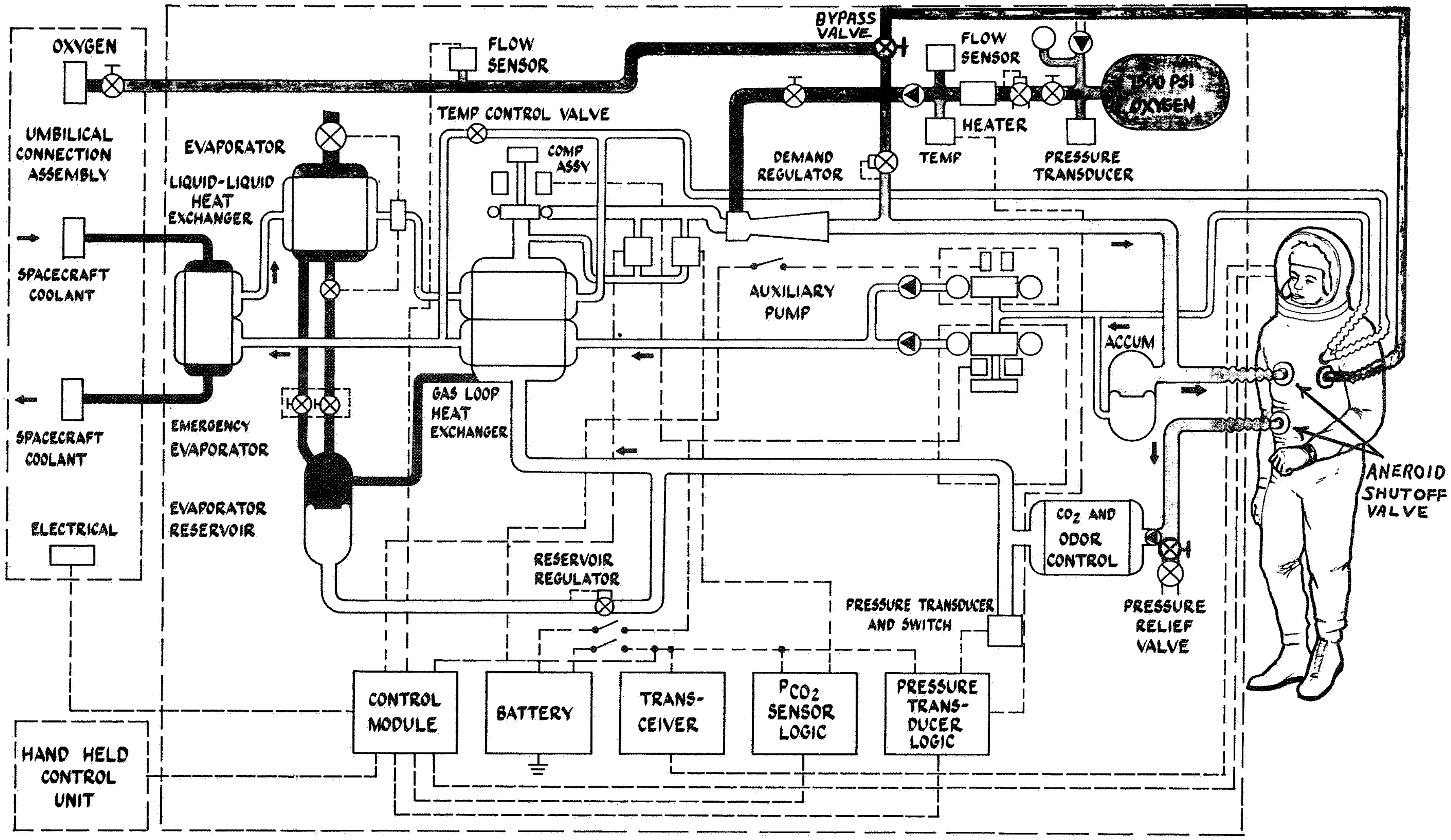

Figure 7.- The PECS with 7500 psi oxygen supply.

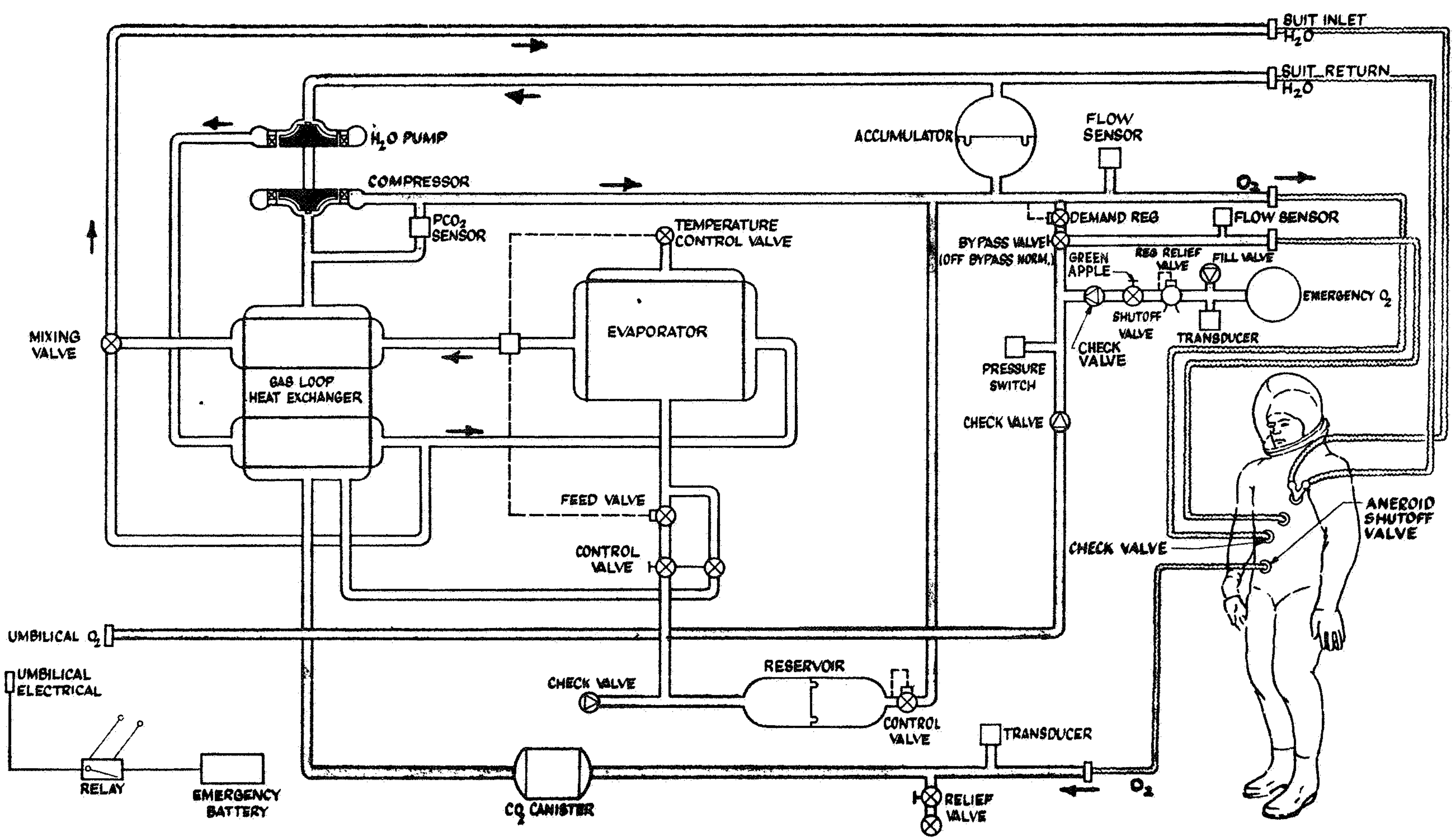

Figure 8.- Electrical/O_2 umbilical, new system.

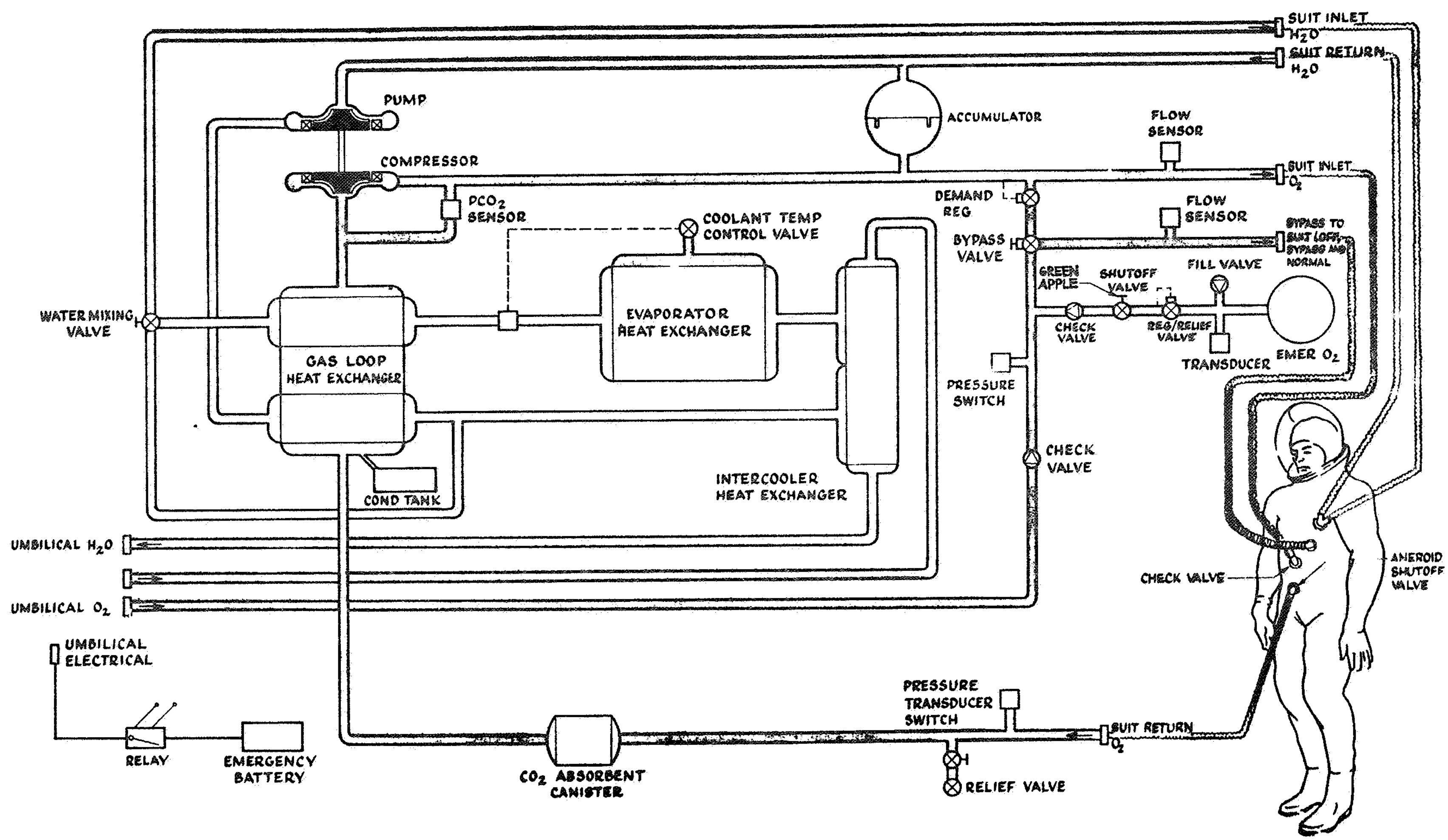

Figure 9.- Electrical/O_2/H_2O umbilical, new system.

Operation Modes

1. Soft suit vented in pressurized cabin
2. Hard suit in vacuum or pressurized cabin
3. Aneroid backup to vacuum exposure

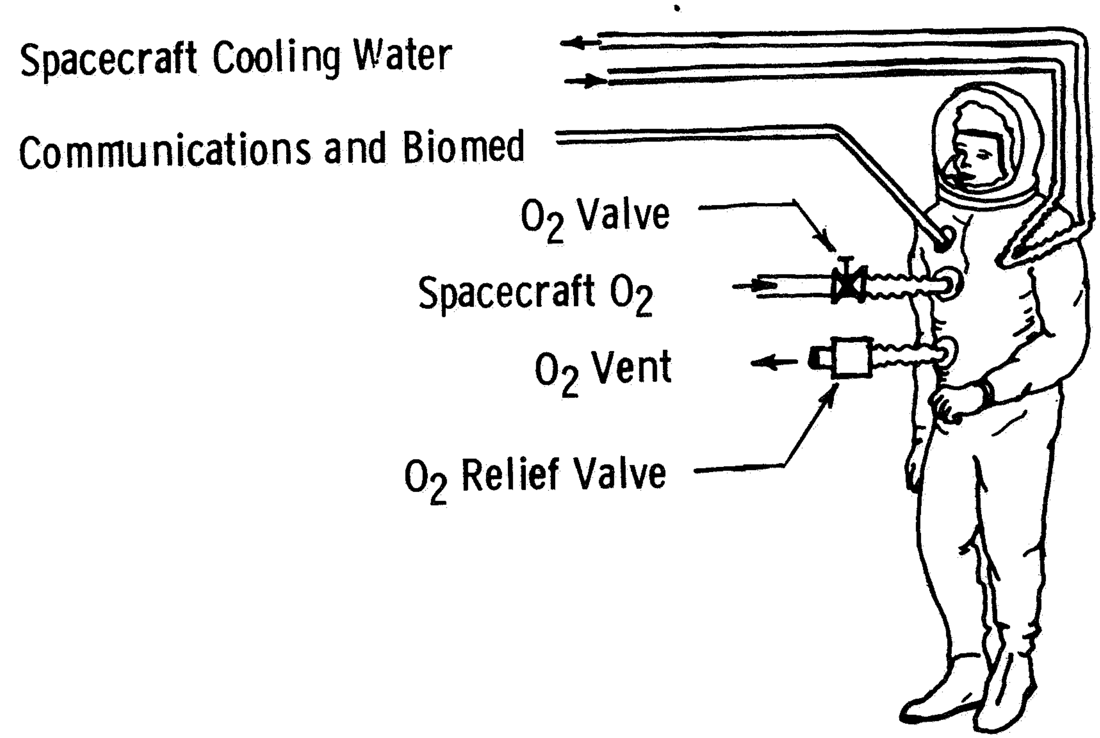

Figure 10.- The AAP suit ventilation unit.